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Modeling of Radio-Frequency Capacitive Discharge under Atmospheric Pressure in Argon

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Abstract—We consider a one-dimensional self-consistent mathematical model of capacitive radio-frequency discharge in Argon between symmetrical electrodes at atmospheric pressure in the local approximation. The model incorporates electrons, atomic and molecular ions, metastable atoms, Argon dimers, and ground-state atoms. The numerical algorithm for the model is based on a finite-dimensional approximation of the problem using difference schemes with subsequent iterations. A software package in the MatLab environment has been developed to implement the numerical algorithm. Using this software for a model problem, we have obtained the characteristics of a radio-frequency discharge in a plasmatron with interelectrode distances of 0.2 and 2 cm at atmospheric pressure. The results of numerical calculations are in good agreement with data known from literature of field experiments and calculations.

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INTRODUCTION

Low-temperature plasma is widely used in many fields of science and technology [1–6]. Among various types of discharges used to obtain plasma, the radio-frequency discharges (specifically, radio-frequency capacitive (RFC) discharges) have a significant place [7–12]. Argon is often used as a plasma-forming gas. To internal and external parameters of a discharge coupled using experimental calculation techniques that mutually complement each other to solve many problems in physics and chemistry of low-temperature plasma [13, 14]. Our previous papers [15, 16] include a review of studies that address the simulation of RFC discharges. Normally, the studies that consider these discharges in Argon assume that the plasma contains electrons, atomic ions, metastable atoms, and ground-state atoms. However, in was found in a study of the dependence of the ratios of the concentrations of molecular and atomic ions in Argon at atmospheric pressure on the gas temperature [17] that molecular ions are dominant at temperatures of around 500 K and the concentration of atomic ions starts growing at temperatures above 1500 K. Therefore, the papers [18–21] solved model problems that take into account electrons, atomic ions, metastable atoms, and ground-state atoms to analyze the dependence of gas temperature and other discharge characteristics on the boundary conditions describing the properties of the electrode sample and concluded that molecular ions and Argon dimers should be included into the kinetic mechanism.

In this study, we take into account the above-mentioned factors and propose a one-dimensional self-consistent model of RFC discharges at atmospheric pressure in Argon. We developed an approximate algorithm for numerical implementation of the proposed nonlinear model on the basis of its finite-dimensional approximation and subsequent use of the iterative method. It should be noted that various iterative methods for solving nonlinear problems, including problems with partial derivatives, have been proposed earlier (for example, [22–26]). However, the problem considered by us has a number of specific features, such as the difference in time scales of the change in main characteristics of the steady-state low-pressure RFC discharge. In addition, a characteristic feature of the problem is the large gradients of

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